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A Genetic Algorithm Approach to the Container Loading Problem

Ana Moura[1, 2]

Rui Rijo[1,3]

[1] INESC Coimbra

[2] Department of Economics, Management and Industrial Engineering, University of Aveiro

[3] ESTG - IPLeiria, Portugal

Outline

1. Container loading problem;
2. Genetic algorithm approach;
3. Approach behavior;
4. Computational tests;
5. Populational Vs non-populational meta-heuristics;
6. Conclusions and future work.

Container Loading Problem

- **Problem:** A set of boxes has to be arranged in one rectangular container in such a way that the container space usage is maximised, subject to geometric and loading constraints;

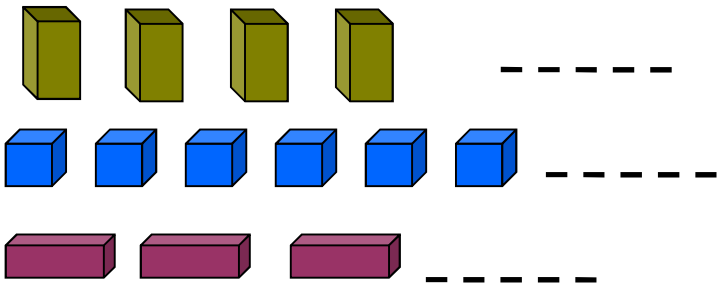
- An arrangement of boxes is feasible if the following conditions hold:
  - Each box is placed parallel to the side walls of the container;
  - The container width and height constraints are satisfied;
  - There are no “intersections” among boxes.

Container Loading Problem

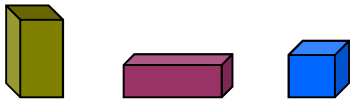
- **Some Problem Constraints:**
  - **Orientation constraint**: each box can be arranged in a maximum of 6 rotation variants;
  - **Top placement constraint**: none of the boxes of a given subset may bear a weight: it is not allowed to place boxes on the top of these boxes;
  - **Stability constraint**: the bottom area of a box should be completely supported;
  - **Balance constraint**: the distance between the center of gravity of the arranged boxes and the middle of the container must not exceed a given percentage of the container's dimensions;
  - **Weight constraint**: the total weight of the loaded boxes must not exceed a given limit.

Genetic Algorithm Approach

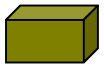
- The basic Heuristic



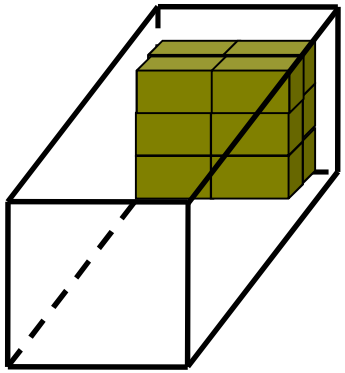
1 - Generate Random Sequence of Boxes



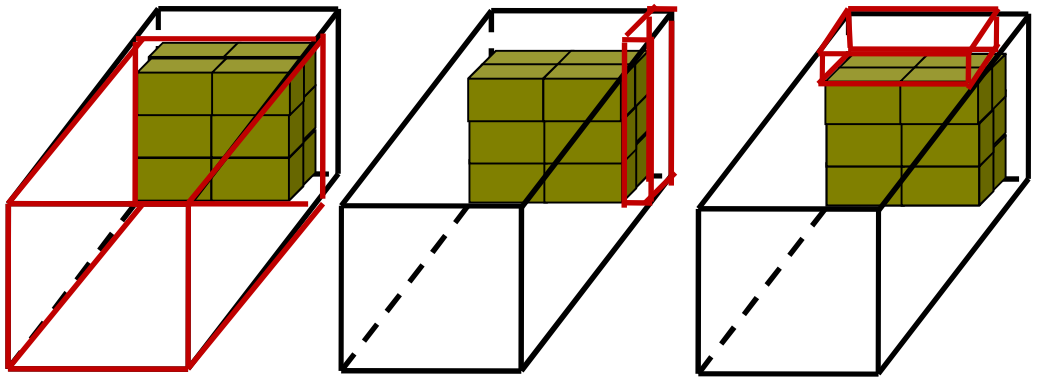
2 - Select a possible orientation Randomly



3 - Build a block and pack

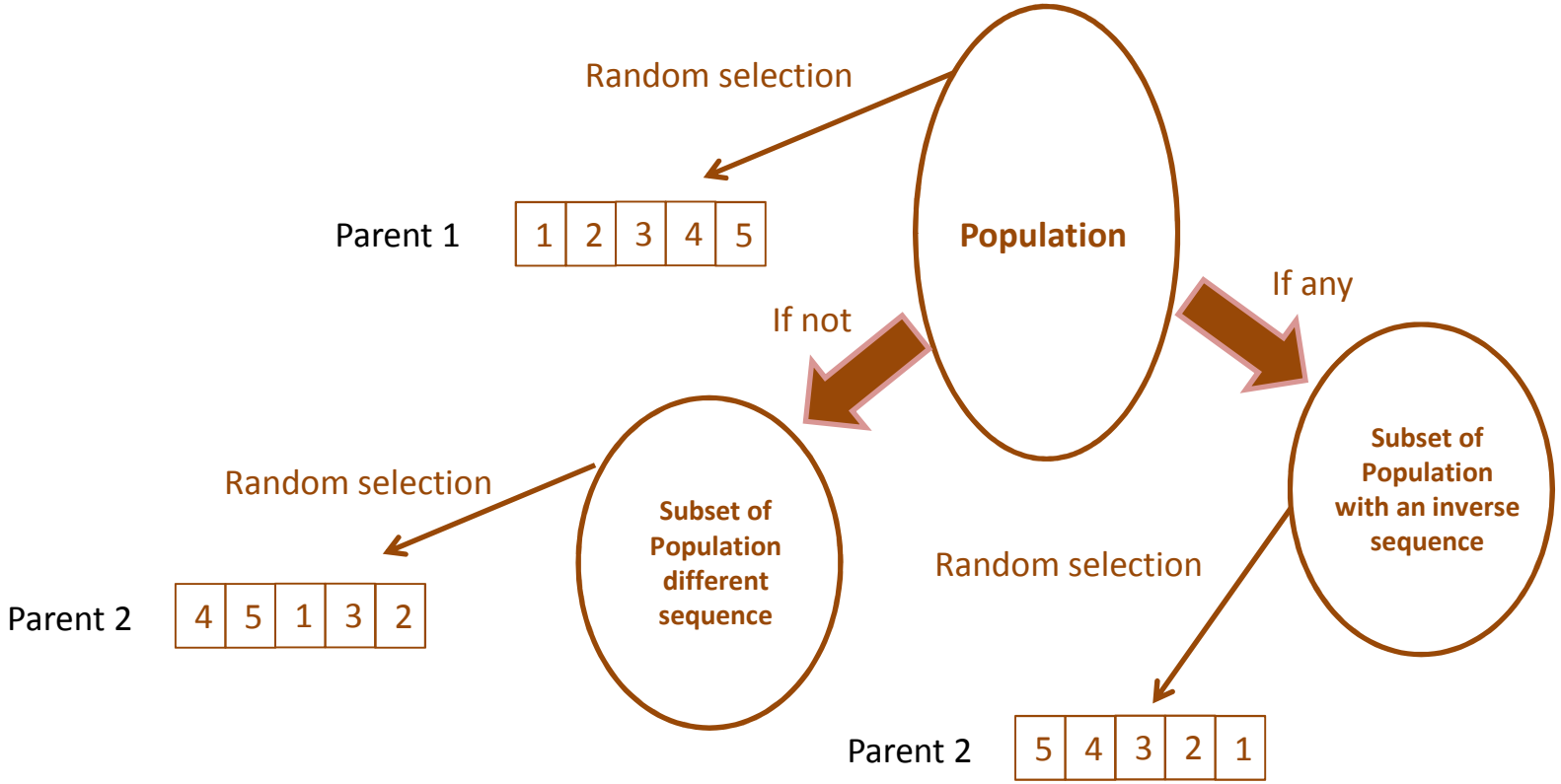


4 - Free spaces generation



Genetic Algorithm Approach

- Fitness Evaluation and Selection
  - Initial population: 240 solutions;
  - Selection for crossover operation:



Genetic Algorithm Approach

- Replacement Strategy:
  - Select the 160 best solutions from the population;
  - Generate 240 new solutions.

  } Diversity

- Crossover Operator
  - Blocks transfer:
    - Parent 1 and 2 – The first set of blocks from the beginning to 70% of the container is selected to be packed in the Offspring;
    - Offspring :
      - Pack the set of blocks from Parent 1
      - Pack the set of blocks form Parent 2
  - Packing extension:
    - Free space generation;
    - Amalgamation;
    - Constructive algorithm.

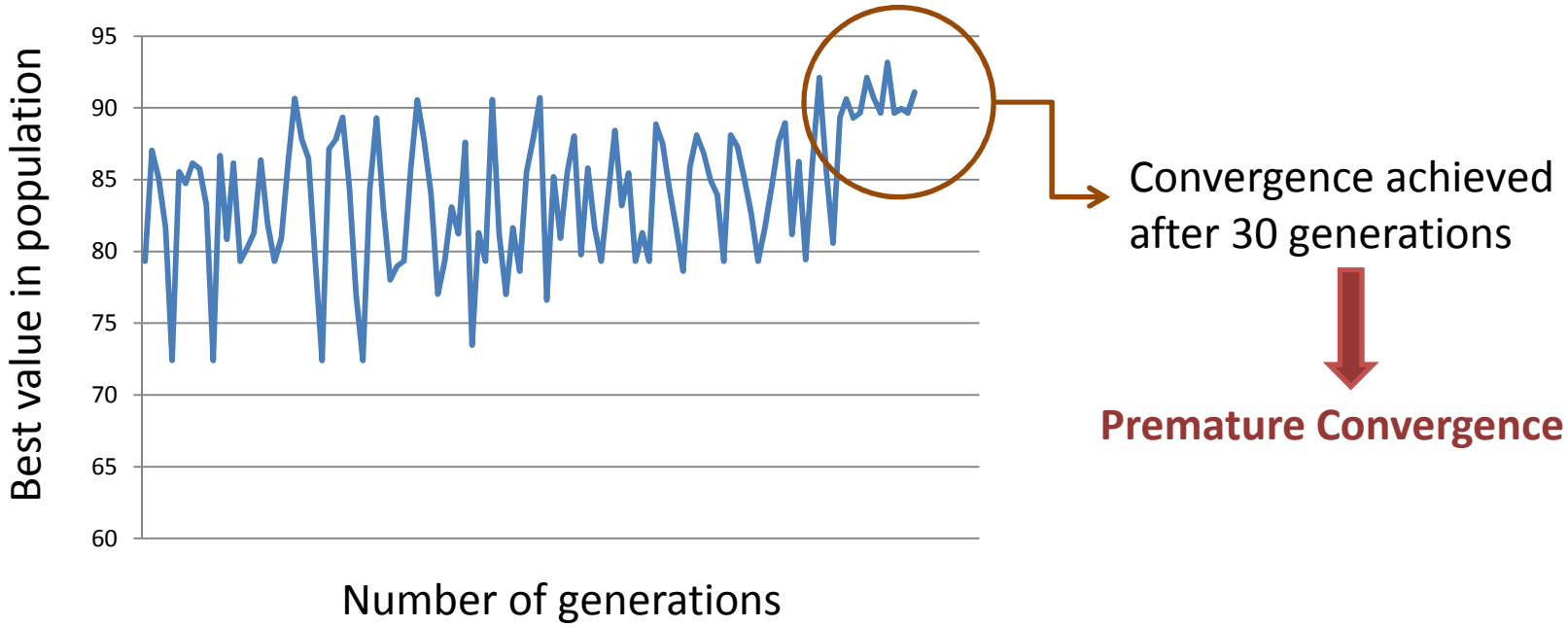
- Stop Criteria:
  - Number of generations

GA Behavior

- The best offspring are achieved when the sequence of the two parents are not totally inversed:

Parent 1 | 1 | 2 | 3 | 4 | 5 | Parent 2 | 5 | 4 | 2 | 1 | 3 |

- **GA Convergence:**



Computational Testes

- Problems provided by Bischoff and Ratcliff
  - 1500 problems subdivided into 15 test data sets;
    - Only orientation constraints are considered;
  - Data sets characteristics:
    - Each data set has 100 problems;
    - Data sets vary from weakly to strongly heterogeneous (from 3 box types in BRD1 to 100 box types in BRD15);
    - The number of box types is equal for all problems of a specific data set;
    - The average number of boxes per box type decreases from 50,2 in BRD1 to 1,3 in BRD15;

Computational Testes

Approach	Constraints	Constructive Algorithm	Method
GB_97	Orientation / Top placement / Stability / Weight / Balance	Towers	Genetic Algorithm
BG_01	Orientation / Stability / Stacking / Weight / Balance	Layers	Hybrid genetic Algorithm
GB_02	Orientation / Stability / Weight / Stacking	Layers	Parallel GA
Jetal_06	Orientation	Layers	Genetic Algorithm
GeneticAlgorithm_CLP	Orientation / Stability	Blocks	Genetic Algorithm

GB_97 – Gehring, H., Bortfeldt, A., 1997. A genetic algorithm for solving the container loading problem. International Transactions in Operational Research, 4, 401-418

BG_01 - Bortfeldt, A., Gehring, H., 2001. A hybrid genetic algorithm for the container loading problem. European Journal of Operational Research, 131(1), 143-161

GB_02 - Gehring, H., Bortfeldt, A., 2002. A parallel genetic algorithm for solving the container loading problem. International Transactions in Operational Research, 9, 497-511

Jetal – Juraitis, M., et al. 2006. A randomized heuristic for the container loading problem: further investigations. Information Tecnology and Control, 1, 35.

Computational Testes

Test Cases (nº off boxes)	Volume Utilization / Dispersions (%)				
	BG_97	BG_01	BG_02 (PM)	Jetal_06	MR_09
BR1 (3)	85,80 (4,40)	87,29 (3,72)	88,10 (3,53)	86,30	**88,49 (3,42)**
BR2 (5)	87,26 (3,03)	89,13 (2,68)	89,56 (2,73)	87,30	**89,77 (1,98)**
BR3 (8)	88,10 (2,20)	90,19 (1,80)	**90,77 (1,57)**	88,00	88,38 (1,64)
BR4 (10)	88,04 (2,05)	90,30 (1,57)	**91,03 (1,51)**	88,10	87,55 (1,55)
BR5 (12)	87,86 (2,02)	90,54 (1,41)	**91,23 (1,44)**	88,20	86,24 (1,70)
BR6 (15)	87,85 (1,82)	90,52 (1,29)	**91,28 (1,19)**	88,20	86,12 (1,54)
BR7 (20)	87,68 (1,43)	90,37 (1,02)	**91,04 (0,96)**	88,40	84,57 (1,69)
BR8 (30)	87,09 (1,34)	89,50 (1,07)	**90,26 (0,95)**	-	-
BR9 (40)	86,12 (1,51)	88,84 (1,08)	**89,50 (1,00)**	-	-
BR10 (50)	85,24 (1,31)	87,98 (1,05)	**88,73 (0,98)**	-	-
BR11 (60)	84,57 (1,42)	87,19 (1,09)	**87,87 (1,10)**	-	-
BR12 (70)	83,98 (1,52)	86,58 (1,11)	**87,18 (1,00)**	-	-
BR13 (80)	83,53 (1,47)	85,96 (1,17)	**86,70 (1,14)**	-	-
BR14 (90)	82,77 (1,64)	85,16 (1,13)	**85,81 (1,08)**	-	-
BR15 (100)	82,23 (1,61)	84,89 (1,04)	**85,48 (1,02)**	-	-
Average Value (BR1 to BR7)	87,51	89,76	**90,43**	87,78	86,20
Average Value	85,90	88,30	**89,00**		

Populational Vs Non-Populational Meta-Heuristics

	Volume Utilization / Dispersions (%)						
Test Cases (nº off boxes)	**Serial Methods**				**Parallel Methods**		
	TS_BGM	**SA_MBG**	**HYB_MBG**	**GRASP_PRO**	**PSA_MBG**	**PHYB_MBG**	**PHYBXL_MBG**
BR1 (3)	93,23	93,04	93,26	**93,85**	93,24	93,41	93,70
BR2 (5)	93,27	93,38	93,56	94,22	93,61	93,82	**94,30**
BR3 (8)	92,86	93,42	93,71	94,25	93,78	94,02	**94,54**
BR4 (10)	92,40	92,98	93,30	94,09	93,40	93,68	**94,27**
BR5 (12)	91,61	92,43	92,78	**93,87**	92,86	93,18	93,83
BR6 (15)	90,86	91,76	92,20	**93,52**	92,27	92,64	93,34
BR7 (20)	89,65	90,67	91,20	**92,94**	91,22	91,68	92,50
Average Value	92,00	92,53	92,70	**93,82**	92,91	93,20	93,78

GA	
Parallel Method	**Serial Method**
BG_02 (PM)	**MR_09**
88,10 (3,53)	**88,49 (3,42)**
89,56 (2,73)	**89,77 (1,98)**
90,77 (1,57)	88,37 (1,66)
91,03 (1,51)	85,83 (1,78)
91,23 (1,44)	85,24 (1,70)
91,28 (1,19)	84,12 (1,54)
91,04 (0,96)	81,57 (1,69)
90,43	86,20

Conclusions and Future Work

- This is a work in progress;
- The GA has a premature convergence

  Mutation operator
- Future Work:
  - Understand the algorithm behavior:

    "Why aren't the best results achieved when an inverse parent sequence is chosen in the crossover operator?"
  - Develop an Hybrid Algorithm.